Desalinization and Wastewater Reuse as Technological Alternatives in an Arid, Tourism Booming Region of Mexico

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Abstract

Los Cabos, Baja California Sur, is one of Mexico's most popular tourist destinations. With 25% of the state's population, it has one of the highest population growth rates in the country mostly due to large-scale tourism development. Economic and population growth mean greater water consumption. The region's main water source is the San José aquifer is overexploited. Private desalinization plants as well as wastewater reclamation plants are becoming important alternative technologies for water management at resort hotels. The projections for population growth and water consumption in the region are alarming. Clearly, there is an urgent need to design renewable resources management strategies, diversify technological alternatives, and design public policies to face the challenges of the future.

Keywords: 1. desalinization, 2. wastewater reuse, 3. population growth, 4. tourism, 5. Baja California Sur.

Resumen

Los Cabos, Baja California Sur, es uno de los destinos turísticos más populares de México. Alberga 25% de la población del estado y presenta uno de los mayores índices de crecimiento demográfico del país, debido principalmente al desarrollo turístico de gran escala. El desarrollo económico y demográfico demanda un mayor consumo de agua, cuya principal fuente de abastecimiento de la región, el acuífero de San José, se encuentra sobreexplotado. La utilización de plantas desaladoras de agua de mar, de propiedad privada, así como de plantas para reúso de aguas negras se ha convertido en un factor fundamental en las estrategias de manejo del agua de los desarrollos hoteleros. No obstante, dadas las alarmantes proyecciones de crecimiento poblacional y de consumo de agua en la región, resulta imperioso desarrollar nuevas estrategias de manejo de los recursos, diversificar las alternativas tecnológicas y diseñar nuevas políticas públicas para enfrentar los desafíos regionales.

Palabras clave: 1. desalinización, 2. reúso de aguas negras, 3. crecimiento poblacional, 4. turismo, 5. Baja California Sur.

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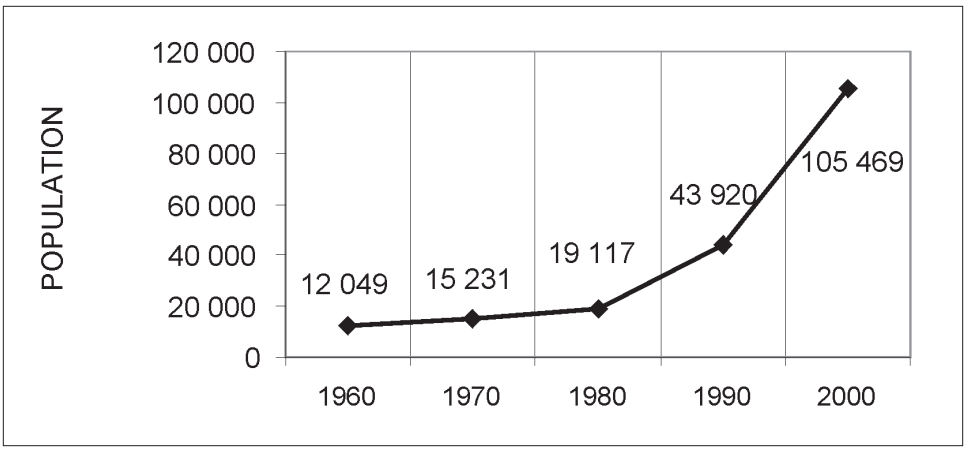
INTRODUCTION

This article examines a major Mexican tourist development located in a very arid region. Water is the limiting factor for growth, and therefore, water planning and management are crucial for success. The focus here is on the role that alternative technologies play in the management of a scarce resource that strongly influences not only the growth but the sustainability of the entire region. Technologies driven by market economics are solving the water and wastewater problems for the resort hotels and large tourist developments. However, the tourist industry is attracting new workers to the region, causing further growth that is creating major social and environmental problems.

One of Mexico's greatest problems is its natural lack of water: more than 50% of the nation's surface area is located in areas of low precipitation (Conabio, 1998). In addition, the unequal distribution of water among the various productive sectors, low water-use efficiency, and the lack of local public policies are factors that affect the sustainable use of this valuable resource. Of all the states in Mexico, Baja California Sur has the least rainfall, almost four times less than the national average (García, 1973). Los Cabos, located at the tip of the state, is a perfect example of a booming tourism development in an arid locale, and it could constitute a case study for other planned developments in the Baja California peninsula. A water crisis is already developing in the region. Desalinization and wastewater reuse are the preferred solutions proposed by decision makers, but local public opinion is resisting these methods. Public perceptions are important factors that shape decision making, and the lack of reliable information is influencing local perceptions about desalinization plants.

For planning purposes, the water supply in Los Cabos and surrounding areas is comparable to that of islands in arid regions of the world (Boutkan, 2004; Domroes, 2001; Garcia and Servera, 2003; Nurse, 2005) and in arid coastal regions with a developing tourism industry (Nativ, 2004; Araus, 2004; Khair *et al.*, 1992; Goh, 2003; Oron, 1998; Bahri, 1998; Postel, 1993). The example of Mallorca, in Spain, has shown that bringing water from distant sources by ship or other means of transportation is inefficient due to the high cost involved (Garcia and Servera, 2003). Growing populations require the production of more water and more efficient use of that resource. Consequently, desalinization of seawater and brackish water, along with planned

water reuse for indirect potable and non-potable applications (such as irrigation) have been growing rapidly worldwide in recent years (Stikker, 2002a, 2002b; Boutkan, 2004; Domroes, 2001; Garcia and Servera, 2003; Nurse, 2005; Nativ, 2004; Araus, 2004; Khair *et al.*, 1992; Goh, 2003; Oron, 1998; Bahri, 1998; Marecos do Monte, 1998; Asano and Levine, 1998; Mills and Asano, 1998; WHO, 2007). These technologies are far more complex and costly than traditional technologies usually applied to relatively good quality freshwater, and they are being used in areas where the need for freshwater is also greater (WHO, 2007). Throughout the world, the practice of desalinization is advancing so fast that it has caught the attention of the World Health Organization, which has developed guidelines in English for health and environmental aspects relating to the technology (WHO, 2007).



Source. INEGI.

FIGURE 1. *Population growth in Los Cabos, Baja California Sur. 1960-2000*

In order to provide guidelines to decision makers responsible for meeting the region's growth and development expectations, we analyzed current legal and political aspects of the water issue. Baja California Sur, perhaps Mexico's most advanced state in water legislation, is the first to address desalinization in its state water law.

Los Cabos encompasses two cities, Cabo San Lucas and San José del Cabo, and a corridor of tourist developments along the coast connect the two cities. For public planning purposes, these three separate entities are one unit.

Baja California Sur has the lowest population density of any Mexican state (5.7 inhabitants per km^2). The Los Cabos area, however, has a strong economy and high growth rates: between 1995 and 2000, it grew at 9.7% annually compared to a national rate of only 1.3% (INEGI, 2001; see figure 1). In 2000, the Los Cabos area had 105 469 inhabitants, 24.87% of the state's total population. This region contributes about one-third to Baja California Sur's gross domestic product.

TOURISM AND SUSTAINABLE DEVELOPMENT

Almost all of the Los Cabos economic and demographic dynamism is dependent on the ability to maintain the environmental and social conditions that attract the large numbers of high-end tourists that characterizes the enclave. Tourism is reputed to be the world's largest industry in terms of international trade, and it is rapidly expanding. The ability of tourism to generate foreign exchange revenue, create jobs, and absorb unemployment gives it worldwide political and social legitimacy. In Mexico, tourism's foreign-exchange earnings are second only to petroleum, migrant remittances, and manufactured goods. The economic benefits of tourism are, however, the result of a fundamental process by which expressions and forms of environmental and cultural capital are traded (Imam and Bashandy, 2003). Environmental capital, in the form of natural resources, constitutes the platform for tourism development.

Most industry brochures fail to indicate that tourism growth in developing countries also drives the creation of working-class settlements, some of them at the margins of legality, with poor infrastructure and services. Attracted to the jobs offered by hotels, large numbers of internal migrants reside in these neighborhoods. Tourism also generates many parallel services, such as restaurants, commerce, banking, insurance, and real estate activities. All these things, and the people associated with them, require public investment in infrastructure and public services, including security, transportation, water and sewage, solid waste management, education, and health care.

The concept of development planning for integrated, sustainable tourism is still in its infancy in the region. Sustainable development can be characterized as a means for making social, economic, and political progress that meets the needs of the present without compromising the ability of future genera-

tions to meet their own needs. The concept of sustainable development has often been identified as the key to understanding the relationship between development and the environment, since the idea calls for a sense of responsibility with respect to human actions and extends the consequences of those actions to future generations. To achieve this, sustainability is indispensable. Throughout the world, and particularly in Mexico, since the latter part of the twentieth century, tourism fueled by globalization has become an official government panacea for achieving "sustainable" development. Long-term social and environmental consequences of tourism, however, have received little or no attention.

METHODOLOGY

This study relied heavily on intensive interviewing, a frequently used technique in the fields of education, sociology, nursing, and communications. It is particularly well suited to topic-specific research (in contrast to research that is situation specific). Intensive interviewing also lends itself nicely to understanding conditions, processes, and events or effects. Intensive interviews strive for what Max Weber called *verstehen*, or deep understanding, grasping the situation from the insider's perspective, or a holistic understanding. In other words, the researcher makes observations, notes general patterns in them, and draws tentative conclusions about the patterns (Schutt, 1999; Rubin and Babbie, 1993; Smith, 1991).

To explore the impact of desalinization and wastewater treatment plants in the Los Cabos area, the authors visited the facilities and conducted intensive, semi-structured interviews with the operations and maintenance managers of nine of the 22 hotels with desalinization and wastewater treatment plants operating in Los Cabos. Additionally, we visited one privately and one publicly owned and operated cluster wastewater treatment plant, serving a group of private residences and one or two resorts, and we interviewed the plant managers. Information was also collected through intensive interviews with key informants: a city councilwoman; the head of the local public utility, Organismo Operador Municipal del Sistema del Agua Potable y Alcantarillado de Los Cabos (Municipio of Los Cabos Water and Sewer Operator, OOMSAPALC); the head of the planning department for the Municipio of Los Cabos (a muni-

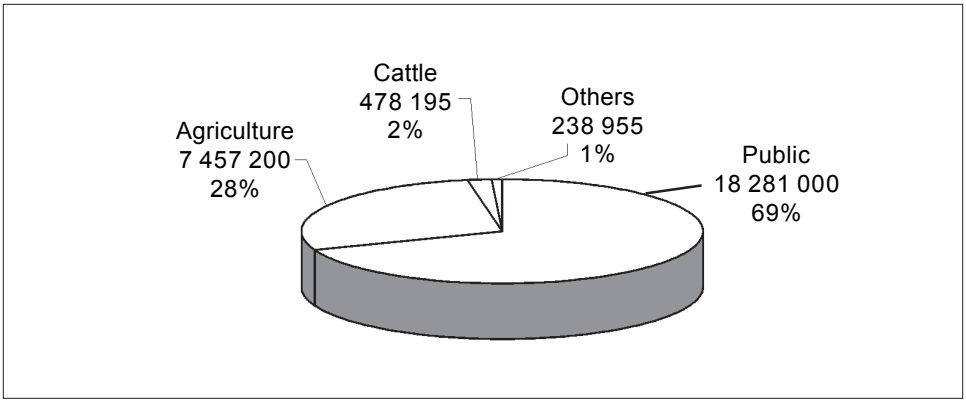
cipio is a political unit roughly equivalent to a U. S. county); the regional manager of the CNA; and the official spokesperson for the local chamber of the hotel industry. Archival information was provided by the municipio, OOMSAPALC, the local CNA office, and the Instituto Nacional de Estadística Geografía e Informática (National Institute for Statistics, Geography, and Informatics, INEGI).

RESULTS

Description of the Region

In the area of Los Cabos, there are 95 hotels, most four- or five-star caliber facilities. There are two marinas, nine golf courses, hundreds of tourist-related businesses, and innumerable condominiums and luxurious real state developments. However, the economic dynamism created by large investments in the tourism sector depends almost exclusively on water extracted from the overexploited San José watershed (CAN, 2004). Due to the continuous increase of the demand of the main users—agriculture, public, urban, and tourism sectors—26.5 million m^3/year (21 480 acre feet) was extracted from the aquifer in 2002, exceeding the estimated natural recharge rate of 23.8 million m^3/year (19 290 acre feet) (figure 2). Even if that estimate is incorrect, the impossibility of increasing the current level of extraction is clear.

Urban development in the Municipio of Los Cabos is governed by a 1999 Master Plan, which is limited and can only be enforced in certain residential areas. The municipio government has a very limited role in the permitting process for resort hotels or large tourism developments because they are mostly built by the Mexican federal authorities, using the Fondo Nacional de Turismo (National Fund for Promotion of Tourism, Fonatur), and the hotels generally pay only federal taxes. Local authorities have no legal power to levy taxes on large tourism developments or hotels. The hotels are also not subject to municipal inspections and many local regulations. Their only contribution to the municipal coffers are a one-time payment for a building permit and annual property taxes. Because most of the decisions about these developments are made in Mexico City, local authorities have little say in these projects and do



Source. CNA, Gerencia Estatal, Baja California Sur.
Prepared by Alva R. Valdez A.

FIGURE 2. *San José Aquifer, 2003 water assignment by sector (cubic meters)*

not share in the profits they generate. Nevertheless, the local authorities must accept, absorb, and try to solve the problems these developments create.

The Master Plan, in this context, becomes a forecasting tool rather than a true planning instrument. The plan requires the installation of a desalinization facility for every new resort hotel built after 1999. However, this regulation should be interpreted as a warning: "We cannot provide you with water since all our reserves are allocated." In addition, it contemplates that, by federal regulation, all wastewater must be treated either locally, that is, in a decentralized wastewater treatment facility, or at a centralized one.

Because new construction occurs at a distance from existing sewer lines, the most widespread choice is the use of decentralized wastewater treatment plants. Although mandated by federal regulations, these plants are subject to few or no inspections by federal authorities, and resort hotels can do whatever they want with their wastewater discharges.

Wastewater Reuse

With this weak regulation, water and wastewater management at resort hotels is almost entirely dictated by market economics. Newly built resort hotels in Los Cabos have no external sources of water. Under these circumstances,

wastewater reuse becomes economically attractive, and a resource to exploit and compete for. Today, almost all the wastewater generated by the resort hotels is treated *in situ* (table 1).

Based on their ownership, the wastewater treatment facilities that we visited varied notably in terms of performance. The public wastewater treatment plant has operational difficulties, mostly due to insufficient treatment capacity, but the smaller, decentralized private wastewater treatment plants of diverse designs were very efficient (for details on design, see Tchobanoglous, 1991). The incentives behind both kinds of operations may explain this difference. Whereas public facilities are designed to mitigate the problems created by wastewater and do not profit from the sale of treated water, private facilities are designed to maximize the reuse of a valuable commodity. Private wastewater facilities contribute to the bottom line of resort hotels. The main incentive for proper wastewater treatment comes from the users themselves.

Almost all the treated water is reused for irrigation purposes; seven out of nine golf courses are irrigated exclusively with reclaimed water, and the other two use water from a dam built for flood control. There are plans to build several more golf courses. A new halophyte grass, Seashore Paspalum (*Paspalum vaginatum*), capable of growing when irrigated with brackish water, is being considered as an alternative to traditional grass, but no study has been done to determine the potential impacts that the introduction of this very aggressive exotic plant might have on the local ecosystem. The factor limiting the growth in the number of golf courses is the availability of reclaimed water, which creates a strong incentive to build, maintain, and operate decentralized wastewater plants with enough treatment capacity to supply the growing demand for reclaimed water.

Water reuse in Los Cabos is entirely market driven with strong limitations imposed by the perceptions of the final users, the hotel guests. Although the high quality reclaimed water produced by most resort hotels could be utilized in different ways, including for doing laundry or flushing toilets, in our interviews, we found only one hotel (one of the newest ones) that uses reclaimed water to flush toilets. Since flushing toilets is a considerable portion of the water consumption per room, this could save considerable potable water, but these plans could backfire in the event of a negative perception of the practice by hotel guests. Unfortunately, due to the highly mobile character of the tourism population, there is no possibility of building public support for pota-

TABLE 1. *Wastewater treatment plants, Los Cabos, Baja California Sur*

Location	Operator	Capacity (lps)	Future increment
Cabo San Lucas	Fonatur-Cabo del Sol	100.00	60.00
	Ravens Country Club	30.00	30.00
	Pueblo Bonito Sunset Beach	2.00	—
	Miramar Development	15.00	40.00
	Subtotal	147.00	130.00
Tourist corridor	Hotel Los Patios	2.00	—
	Costco	2.00	—
	Villas Neptuno	2.00	—
	Amalfi (Pueblo Bonito)	2.00	—
	El Tezal	2.00	—
	Misiones del Cabo (two plants)	4.00	—
	Cabo Bello	2.00	—
	Esperanza Resort	2.00	—
	Punta Ballena	10.00	—
	Desarrollo Cabo del Sol	15.00	—
	Hotel Twin Dolphin	2.00	—
	Hotel Calinda	1.50	—
	Hotel Cabo San Lucas	2.00	—
	Cabo Real	15.00	—
	Hotel Gran Marquiz	3.00	—
	Hotel Westin	15.00	—
	Desarrollo Palmilla	30.00	—
	Subtotal	111.50	0.00
San José del Cabo	Condominio La Joya	2.00	—
	Fonatur	150.00	—
	Infonavit Las Veredas	5.00	—
	Aeropuerto Internacional	2.00	—
	Subtotal	159.00	0.00
Delegations	Miraflores	3.10	—
	Santiago	—	3.10
	La Rivera	—	3.10
	Subtotal	3.10	6.20
	Total	420.60	136.20

Source. Municipio of Los Cabos, Baja California Sur, 2005.
Note. A delegation is a subunit of a municipality that contains one or more neighborhoods.

ble water reuse through education (Wegner-Gwidt, 1998). Reclaimed water use will remain limited to irrigation and other non-potable uses for the foreseeable future (McEwen, 1998).

However, although reused water is not currently being considered as an alternative source for human consumption, local water managers ought to consider that as the next step to take. The introduction of a separate reclaimed water delivery system, like the "purple pipe" of California, could increase the water availability for the rest of the population by replacing "good" water with reused water for certain specific uses, such as flushing toilets and irrigation (Young *et al.*, 1998). Also, the large volume of wastewater poorly treated in public utilities that are creating a pollution problem in the area could be put to a good use if properly treated. For example, the Orange County Water District, in California, runs the Water Factory 21 that is currently injecting 15 mgd (million gallons per day) of a blend of reclaimed wastewater and deep well water into the Santa Ana aquifer to maintain the hydrostatic pressure of seawater intrusion barriers (Mills *et al.*, 1998). The recycled product water from Water Factory 21 meets drinking water standards through treatment using advanced processes (McEwen, 1998). Recycled water was chosen for many reasons. Cost was a definite consideration, but even more important were the environmental advantages, such as reduction of wastewater discharged into the ocean, reduced dependence on other sources of supply, and a constant availability of a water supply to support the seawater intrusion barriers (Mills *et al.*, 1998; Orange County Water District, 2007).

A public-private model could be developed to produce high quality reclaimed water for use in crop irrigation and green areas or to recharge aquifers. A market for reclaimed water already exists, and with proper encouragement, it should become a key player in water management in Baja California Sur.

Desalinization and Tourism Development

In this environment of strong resort hotel growth, desalinization of sea water is fast becoming the preferred solution for increasing the water supply and overcoming the strong psychological barriers to using reclaimed water for indirect potable reuse (Wegner-Gwidt, 1998; McEwen, 1998). Interviews with the operations and maintenance managers of desalinization plants in the area

showed that in general all desalinization plants perform properly, the technology is reliable, and hotels depend on them. Operations and maintenance managers in the local hotel industry run all the behind-the-scene operations, from laundry to water treatment, from repairs to food preparation. These managers, second in command only to the hotels' general managers, are responsible for all maintenance and operations budgets. Their decisions are based on market economics; they must provide services that meet the needs of guests at the lowest possible cost. No independent quality control is performed on the unregulated desalinization plants, but since hotel guests demand good water quality (and include that criterion when judging the hotel), managers take the initiative to perform periodic quality control tests.

During our interviews, we found that the hotel desalinization plants all use reverse osmosis (RO), consisting of bundled membranes placed in a pressure chamber, a high pressure pump, a turbine for recovering energy from the high concentration brine that is discharged from the plant, and a system for the pretreatment of the feed water and the product water (Einav *et al.*, 2002; WHO, 2007). All the plants also have a modular design with a capacity of 200 m^3 (52 830 gallons) per day per module. On average, the reported power consumption was 70.5 kWh per day per module. The power consumption per unit volume, however, could not be estimated since accurate data on output were not available and also because plants operate only for a few hours per day, usually at night to take advantage of cheaper power rates. The total desalinization capacity installed in the region is 2 647 067.6 m^3 (2 146 acre feet) per year, which means consumption of 535.12 MWh per year or a daily demand of 1.46 MWh. Thermoelectric power plants located outside the Los Cabos area cover that demand in full. The region has two operating plants located near La Paz: Punta Prieta II built in 1979 with a capacity of 113 MWh, and the recently finished Baja California Sur I with 41.3 MWh. A third plant is under construction (Baja California Sur II) with an estimated capacity of 42.8 MWh. The Comisión Federal de Electricidad (Federal Commission of Electricity, CFE) guarantees the provision of 70 MWh to the municipio. Energy production does not appear to be a limiting factor for the expansion of the technology in the near future.

Most of the impact on the marine environment is a consequence of the positioning of the feed pipes and the brine discharge pipes. The common practice in Los Cabos is to use a well in the sand as an inlet and another tube,

TABLE 2. *Private desalinization plants in Los Cabos, Baja California Sur*

Name	Production m^3/day	Annual capacity (m^3)	Number of rooms*
Hotel Pueblo Bonito-Sunset Beach	1 460	532 900	973
Hotel Tanimara	864	315 360	576
Hotel Finisterra	647	236 155	431
Hotel Playa Grande	534	195 001	356
Hotel Villa del Palmar	474	173 010	316
Hotel Fiesta Americana	432	157 680	288
Cabo Marina	413	150 563	275
Hotel Holiday Inn	321	117 001	214
Hotel Plaza Las Glorias	220	80 300	147
Hotel Cascadas	200	73 000	133
Hotel Royal Solaris	180	65 700	120
Hotel Hilton	180	65 700	120
Hotel Melia Los Cabos	180	65 700	120
Hotel Solmar	180	65 700	120
Condominios Gardenias, Cabo Real	160	58 491	107
Desarrollo Cabo Real	148	53 998	99
Quinta del Golfo de Cortez	148	53 984	99
Villas Baja	130	47 304	86
Hotel Coral Baja	118	43 201	79
Desarrollo Campestre Callisto	114	41 501	76
Hotel Pueblo Bonito Blanco	82	29 999	55
Colonos del Pedregal	68	24 820	45
Total	7 252.24	2 647 067.60	4 835

Source. Comisión Nacional del Agua, Gerencia Estatal, Baja California Sur.
*Number of rooms that can be supplied with the installed capacity, estimated use of 1.5 m^3/room/day.

at a far distance, for direct discharge of the brine. In general terms, the main environmental impact of desalinization plants is due to the discharge of the concentrated brine into the sea, and its magnitude depends on environmental and hydrogeological factors characteristic of the sea (Einav *et al.*, 2002). Studies of the effects of the discharge on the environment have not been performed in Los Cabos. Direct observations showed that discharges took place in sandy beaches displaying strong waves. High-energy sandy oceanic coasts, with coast-parallel current, are the least sensitive of all receiving marine ecosystems (Einav *et al.*, 2002). Since there is a distance of several miles between each plant, the impacts of the brine discharge are scattered over a large area. In the absence of monitoring, anecdotal information from hotel operators is the only source of information available. Operators are only concerned about macro-level impacts that could potentially damage their image, like smells, floating debris, or massive fish die offs, and such events have not occurred. When questioned, managers defended their practices by noting that they had not observed any negative effects on their beaches. Indirect evidence seems to support the claim that the present levels of brine discharge have little environmental impact. One of the area's main attractions is its small reefs, with their abundant fish, and most hotels provide their guests with snorkel gear to visit them. There has been no anecdotal evidence of a depopulation of those reefs. For the time being, the "solution to pollution is dilution" position seems to be working, at least at a macroscopic level. However, implementation of systematic studies of the ecological effects of brine discharges is urgently needed (WHO, 2007).

All the hotels have back-up power generators, so that the facilities can be self-sufficient for several days in the event of a major natural disaster. This independence from the public utilities is very important for the businesses, since Los Cabos is frequently hit by hurricanes that sever water and power supply for hours or even days at a time. Currently, new hotels built in the area are not allowed to buy water from the public utility, and they must solve their water and sanitation requirements on their own. Older hotels have water-supply contracts with the public utility, but economics is an incentive for them to install their own desalinization plants. This water costs about half the price charged by the public utility. But, fundamentally, older hotels are choosing to install desalinization plants to ensure reliability in the supply and override the limitations imposed by the public utility to the supply of the sector.

All hotel managers who were interviewed stated that the primary reason for purchasing a desalinization system was to ensure the water supply for their guests, since the municipal public utility imposes strict limitations. However, after several months of operation, another advantage became evident to them: Desalinization plants provide source reliability, which is nowadays perhaps the most important reason to seek independence from the public water system. Hotels cannot afford to be without water for their guests. In the event of an interruption of service, they must purchase water immediately at any cost and from any available source. A major event that changed perceptions was Hurricane Juliette, which hit the Los Cabos area in 2001. In the storm's wake, water and electricity service was interrupted for almost two weeks throughout the area. Older hotels that depend entirely on the public water supply had to scramble to rent tankers to truck in the water from distant sources at a very high cost. Additionally, the recent drought has led to water rationing, which affects all users, including hotels.

An interesting new development is an increased reliance on local companies to maintain and service the plants. Although most hotels purchased their desalinization technology in the United States, some interviewees indicated that locally owned plant-servicing companies are jumping into that market niche.

Population Growth, Water Management, and Desalinization

The use of water desalinization processes by resort hotels has had unintended consequences through the indirect creation of major social and environmental problems for this area of Mexico. As Garrett Hardin's First Law of Ecology states, "We can never do merely one thing." The forces of technology and market economics are creating a scenario akin to the "Tragedy of the Commons" (Hardin, 1985).

Although economics, rather than regulatory prescriptions, have forced resort hotels to solve their own water and sanitation problems, the government of the municipio of Los Cabos must face the reality that with its available resources, they cannot meet the water-resource needs of the continuously growing population that has been created by the influx of workers migrating to the area to take advantage of the large number of jobs generated by the hotel industry.

Paradoxically, the same technology that generated the problem is now being considered as a way to solve the unintended secondary effects. Desalinization, as it is used today in Los Cabos, benefits only the hotels. By making the hotel viable, a large number of labor immigrants are drawn to the area. Mexican law dictates that the needs of this population must be supplied by the local municipal authorities. Thus, services for these immigrants are "externalities" of the hotel industry that the local government is forced to absorb (Panayotou, 1993). According to INEGI data (2001), each new hotel room built in the area is estimated to attract 19.1 new migrants, mostly from other areas of Mexico but also highly skilled workers from other countries that have well-developed tourism industries. It falls to the public sector to solve the resulting water supply problems. In the Los Cabos area, the exploitation of the aquifer is at capacity, and there is little maneuver room for reallocating the existing supply among users, and potential water sources are too distant to build aqueducts. Therefore, the desalinization of seawater to supply the predicted increase in population is by far the best of the available alternatives.

The continuous growth of the large-scale tourism industry in Los Cabos is only possible because of the technologies that provide that sector with new sources of water, through desalinization and wastewater reuse. Indeed, the level of the tourism sector's water consumption from OOMSAPALC has been stable since 1997 (figure 3).

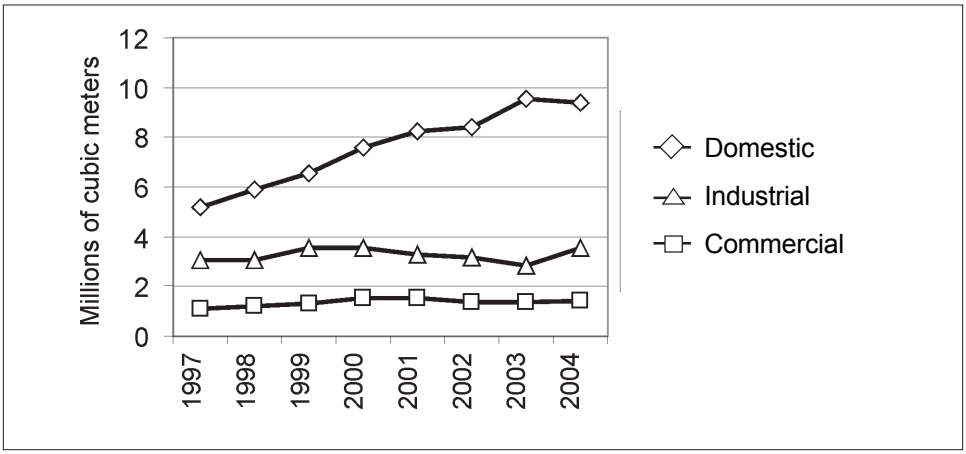
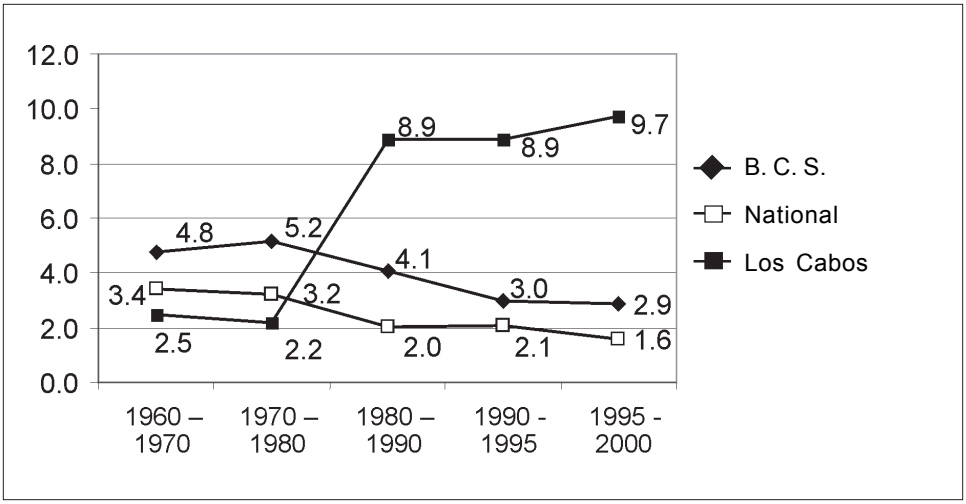


FIGURE 3. *Water consumption by sector in Los Cabos, Baja California Sur. 1997-2004*

Although tourist-sector water consumption is stable, residential use has increased substantially (figure 3) and even greater increases are predicted. Los Cabos has one of Mexico's highest population growth rates, as a result of jobs generated by the steady increase in hotel accommodations. Between 1993 and 2003, both hotel rooms and population grew at an annual average rate of 7.6%, and if the trend continues through 2025, the area will have approximately 44 000 hotel rooms and 845 000 residents (Ochoa, 2005). For planning purposes, OOMSAPALC uses a basic residential consumption rate of 250 liters (or 66.04 gallons) per capita per day (SAPALC, 1996) to estimate that by 2025 the population will require approximately three times the current volume of water extracted from the aquifer.



Source. Population and Housing Census, INEGI.

FIGURE 4. *Annual population growth rates. 1960-2000*

Based on these projections, by 2025, the total number of hotel rooms added to the region will be 34 752. Assuming that all new developments will have to use desalinization to cover their water needs, and the current estimated consumption of 1.5 m^3 (or 396.3 gallons) per room per day continues, the requirements at that point will be 52 128 m^3 (13 770 000 gallons or 42.26 acre feet) of water per day. To cover that demand, hotels will have to install 261 new RO desalinization modules with a capacity of 200 m^3 per day. By that

point, the Los Cabos area will be home to 693 356 new inhabitants. Assuming a consumption of 250 liters (66.04 gallons) per inhabitant per day (SAPALCN, 1996), the increased demand will be 173 339 m^3 (45 790 000 gallons or 140.5 acre feet) per day. If desalinization plants were to cover all that demand, 867 new RO desalinization modules with a 200 m^3 daily capacity would have to be installed to quench the resident population's thirst.

TABLE 3. *Increase in Los Cabos hotel rooms and area population, through 2025*

Year	Rooms	Increase	Population	Increase
2004	9 512	—	152 086	—
2006	11 011	1 499	180 015	27 929
2010	14 757	3 746	244 867	64 852
2015	21 282	6 525	371 125	126 258
2025	44 264	22 982	845 442	474 317

Source. Proyecto Los Cabos 2025, FOA, S. C., 2004.

TABLE 4. *Projected demand for services in Los Cabos in 2030*

Services	Forecast
Water (lps)	2 570
Sewer (lps)	2 056
Electricity (kWh)	520 438
Telephone	76 286
Housing	216 780

Source. Proyecto Los Cabos 2025, FOA, S. C., 2004.

All water legislation in Mexico comes from the top down. Federal and state regulations, although adequate on paper, are not easily enforced at the city level. In recent years, some progress in the water management consultation process has been made, yet, the opinions and interests of the lower echelons of power (individual users, cities, and counties) are not fully represented in the decision making process. This creates some anxiety at city levels, since

those officials are left to solve the problems created by growth but without receiving economic or legal resources to do so. The implementation of national and state-level policies at the local or grass-root level is still inefficient despite all the recent efforts.

The current Master Plan for Los Cabos is eight years old, and by now, as a forecasting tool, it is no longer useful. Among other things, the area's population has already surpassed the size predicted in 1999. An updated Master Plan, with characteristics specifically designed for Mexico, is urgently needed. During its preparation, all sectors should be included in the process, through a novel approach to planning sustainable tourism developments in coastal areas. That effort could set an example for the rest of Mexico, but it will require the voluntary involvement and commitment of the tourism sector. The plan's objective will be to assist stakeholders in the planning and management of the coastal area while contributing to the conservation of its natural diversity. The new plan should provide a set of well-defined guidelines for the planning and design of environmentally sound, aesthetically pleasing, and market-sensitive development of the region's tourism.

Public Desalinization Plant

Since no extra water can be extracted from the aquifer and the population continues to grow rapidly, the only viable alternative is to extract freshwater from the sea. OOMSAPALC is the first-ever public utility in Mexico to take steps to desalinize water for domestic users. Out of necessity, an innovative mechanism for Mexico—a public-private partnership to build and operate a desalinization plant—is being developed in Los Cabos.

Public-private partnerships (PPP or P3) are arrangements between government and private sector entities for the purpose of providing public infrastructure, community facilities, and related services. Such partnerships are characterized by the sharing of investment, risk, responsibility, and reward between the partners. The reasons for establishing such partnerships vary, but generally they involve the financing, design, construction, operation, and maintenance of public infrastructure and services. The underlying logic for establishing partnerships is that both the public and the private sector have unique characteristics that provide them with advantages in specific aspects

of service or project delivery. The most successful partnership arrangements draw on the strengths of both the public and private sector to establish complementary relationships. "Public-private partnership is one of a number of ways of delivering public infrastructure and related services. It is not a substitute for strong and effective governance and decision making by government. In all cases, government remains responsible and accountable for delivering services and projects in a manner that protects and furthers the public interest" (CMMA, 1999:5).

The PPP model has been successfully implemented in the U. S. water and sanitation sector, including in these major cities: Atlanta, Seattle; Keystone (South Dakota); Veolia and Tampa Bay (Florida); Indianapolis; El Paso; and Burlingame (California) (NCPPP, 2007). Canada's experience with PPPs has been limited, mostly due to high levels of public investment in infrastructure that leave little room for private investment. A regulatory change was enacted (CMMA, 1999) to give PPPs a solid legal framework, and it is anticipated that step will increase the number of PPPs in the Canadian water sector in the near future (Ouyahia, 2006). From experiences in Senegal, Ghana, and Lesotho, it is clear that PPPs in the water sector in Africa have not had the desired results, due mostly to poor planning (UNESCO, 2005). According to Constantine Ogunbiyi (2004:1), several schemes have had a "negative impact on the poorest of the poor by restricting their access to clean supplies due to high tariffs". Experiences with PPP in Latin America in countries like Argentina, Brazil, Costa Rica, El Salvador, Nicaragua, Peru, Uruguay, Bolivia and Chile are in their early stages, and more studies are needed to assess the strengths and weakness of the model in the region (PPPUEM, 2007). The public desalinization plant that is being built in Los Cabos is the first of its kind in Mexico. The initial output is an estimated 200 liters per second although that is predicted to increase as the population grows. The original cost was estimated at 285 million pesos (IOA, 2005). Even though it faced some delays due to land tenure problems, it began operating in November 2006 and was inaugurated by President Felipe Calderón Hinojosa in April 2007. It is a pilot project that is very valuable in many senses, and it could be used as a model for the rest of Mexico's tourism developments. This is the first attempt in Mexico to use a public-private partnership to build, operate, and maintain a desalinization plant to serve domestic users. The project will serve three existing peri-urban neighborhoods (*colonias*) with a high index of marginalization (that is, the lowest

socioeconomic strata). The plant built and operated by a Spanish company, INIMA, that sells the water to the OOMSAPALC, which in turn stores, distributes, sets user fees, and maintains and operates the distribution network. The price of the water was originally estimated at 8.5 pesos per cubic meter (IOA, 2005). After few months of operation, the cost was re-estimated at between 11 and 14 pesos per cubic meter, with a fixed cost of 8.98 pesos from the desalinization process and variable costs accounting for the difference. Users are charged 3.33 pesos per cubic meter as a basic residential rate (Leandro Santiago Sánchez, Social Communications Coordinator, OOMSAPALC, June 15, 2007, pers. comm.). Thus, to cover the costs of production, their water consumption has to be subsidized.

The project also included the construction of a delivery system (water pipes), built and maintained by INIMA, the company that won the bid, and a sewer system consisting of sewer lines and a decentralized wastewater treatment plant, to be built and operated by a another company that is yet to be determined. This part of the plan created some tension since many strong regional economic interests were competing for the allocation of what has locally become a very valuable resource. That contributed to the delays in the construction and operation of the system.

CONCLUSION

A large tourism development is taking place in one of Mexico's driest regions, the area in and around Los Cabos in Baja California Sur. Water availability is the limiting factor for its growth. Desalinization is the main technology that is allowing the hotel industry to overcome the limits imposed by nature. However, the vibrant hotel industry has stimulated strong migration to the region. Once all the natural water resources had been allocated, desalinization was the technique used by the public utility, OOMSAPALC, to produce the additional water needed to serve the growing community of immigrants.

Perhaps the most important challenge faced by the managers of the public utility is the design of mechanisms to spread the higher costs of desalinized water to all the population it serves (Renwick and Archibald, 1998; Haddad, 2000; Loaiciga and Stephen, 1977). Under the current price structure, the cost of producing desalinized water is about five times what customers at the

low end of the consumption scale pay for their water bill. In contrast, customers at the high end of the scale pay ten times more for the same volume of water than do the low-consumption users. Since the trend of reducing the water supplied to hotels will have to continue in order to supply the growing demand of domestic users, the public utility faces a scenario in which there will be less income from high-consumption customers, which will reduce the resources available to subsidize the low-consumption customers. Thus, finding new sources to fund that subsidization is critical.

The current Master Plan provides for the creation of a trust fund (*fideicomiso*) that will be funded by voluntary contributions from large developers to compensate for the secondary effects on the local infrastructure of the growth they generate. This trust fund has yet to be implemented, primarily because of strong opposition from the tourism sector. However, the fund may be the only viable short-term solution, since local hotels contribute little in taxes to the city coffers, with their main contribution coming from the purchase of building permits and the payment of property taxes. In Mexico, local city managers have little power to enact and collect new taxes.

Nevertheless, there is at least one example of shared co-responsibility by the tourism sector for the growing pains experienced by Los Cabos, which could be used as a model: a few years ago, the tourism sector voluntarily enacted a 1.3% room tax to be used to build a specific infrastructure project that benefited them. When the project was completed, the tax was repealed. Even though there is a strong opposition from the sector, a similar tax is probably the only solution to the infrastructure problems created by the continuous addition of new hotel rooms in this part of Baja California Sur.

The solution to not only to the water shortage in Los Cabos but to the challenge of sustainable development of the region lies with the actors themselves. They must be creative in finding new solutions, since the old paternalistic approach of the Mexican welfare state is no longer possible. Private-public partnerships and strong economic participation in infrastructure provision by the sectors that are fueling the population growth are the only viable long-term solutions to maintain both economic growth and social harmony in this booming region. Tourism developers must realize that their current growth rate can only continue if they internalize present-day externalities and help the government of the municipio supply services to the large volume of migrants attracted to the region by its vibrant tourism industry.

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